Granular Explosives and Initiation Sensitivity

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Plastic-bonded explosives are heterogeneous materials consisting of explosive crystals held together with a binder material. In addition, a couple of percent void faction is unavoidable in the manufacturing process. The voids play a crucial role in the initiation sensitivity. When subjected to a compressive wave, the voids collapse giving rise to localized peaks in the temperature field called hot spots. Reaction rates are extremely sensitive to temperature. As a consequence, hot spots dominate the initiation of a detonation wave.

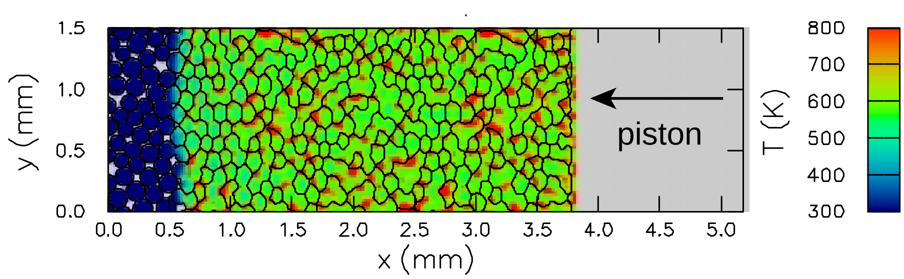

Figure 1: Piston driven compaction wave in granular HMX. The granular bed has a porosity of 19%. The piston is impulsively started at the right boundary with a velocity of 1000 m/s. Black lines indicate interface between grains. The temperature field is displayed at a time of 1.4 µs after the start of the piston.

Weak preshocks can close the voids and desensitize an explosive. In contrast, damage to an explosive increases the porosity and greatly increases ignition sensitivity. Damaged explosives are frequently involved in accidents. Predicting initiation sensitivity is an important issue for explosive safety.

A granular explosive is a suitable model, albeit simplified, for a damaged explosive. It captures the dominant features of a damaged material; a heterogeneous length scale from the grain size and an additional degree of freedom from porosity. Continuum mechanical simulations that resolve individual grains are being used to develop a better understanding of how the hot spot distribution varies with mechanical stimuli.

Mesoscale simulations are a tool for studying explosive initiation that is dominated by physical processes occurring at spatial and temporal scales too small to measure with currently avilable experimental techniques.

The result of a piston driven compaction wave in a granular bed is shown in Figure 1. Initially, grains of the explosive HMX 0.14 mm in diameter are randomly distributed and tightly packed to yield a porosity of ~19%. The piston at the right boundary is given a velocity of 1000 m/s. The high-stress concentrations generated at the contact between grains cause the grains to deform plastically and squeezes out the pores. The temperature field shows that hot spots are subgrain in size and occur around the contact surfaces between grains. Figure 2 shows the temperature profile in the direction of wave propagation. The average profile represents a shock wave. The rapid rise at the shock front is a couple of grains wide. The change across the front satisfies the shock-jump conditions set by the conservation laws. However, the heterogeneities give rise to fluctuations with peak temperatures significantly greater than the average. The temperature distribution (mass fraction vs. temperature) shown in Figure 3 better characterizes the fluctuations. Hot spots correspond to the tail of the distribution. For this relatively strong wave, the hot spots include 30% of the mass behind the front. Prompt initiation, within a few microseconds, would occur if reaction were included in the simulation.

For explosive applications, the feasible cell size is much greater than the scale of a grain. The limited resolution necessitates using a homogenized constitutive relation for the explosive. Furthermore, temperature fluctuations on the scale of a grain are eliminated by the homogenization and burn models are needed to account for the effect of hot spots on the reaction rate. Mesoscale simulations are a tool for gaining an understanding of the physics at small spatial and temporal scales needed to develop better burn models. More details can be found in the reports "Compaction Wave" [1] and "Initiation Sensitivity" [2].

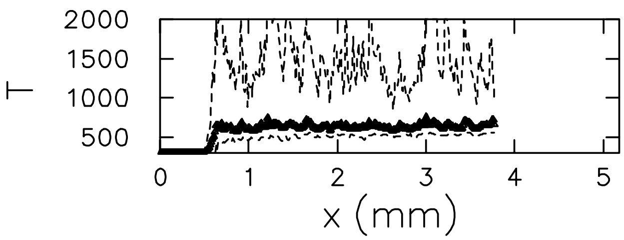

Figure 2: Temperature profile (dashed lines correspond to the minimum and maximum values).

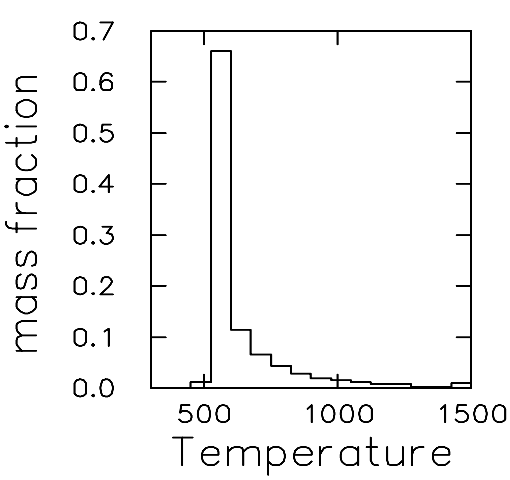

Figure 3: Temperature distribution behind compaction wave (2.5 mm < x < 3.5 mm).

[1] R. Menikoff and E. Kober, "Compaction waves in granular HMX," *Tech. Rep.* LA-13546-MS, Los Alamos National Laboratory, 1999. Also, available online from LANL Library.

[2] R. Menikoff, "Granular explosives and initiation sensitivity," *Tech. Rep*. LA-UR-6023, Los Alamos National Laboratory, 1999. Available on line, http://t14web.lanl.gov/Staff/rsm/Papers/IMA Initiation.pdf.

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